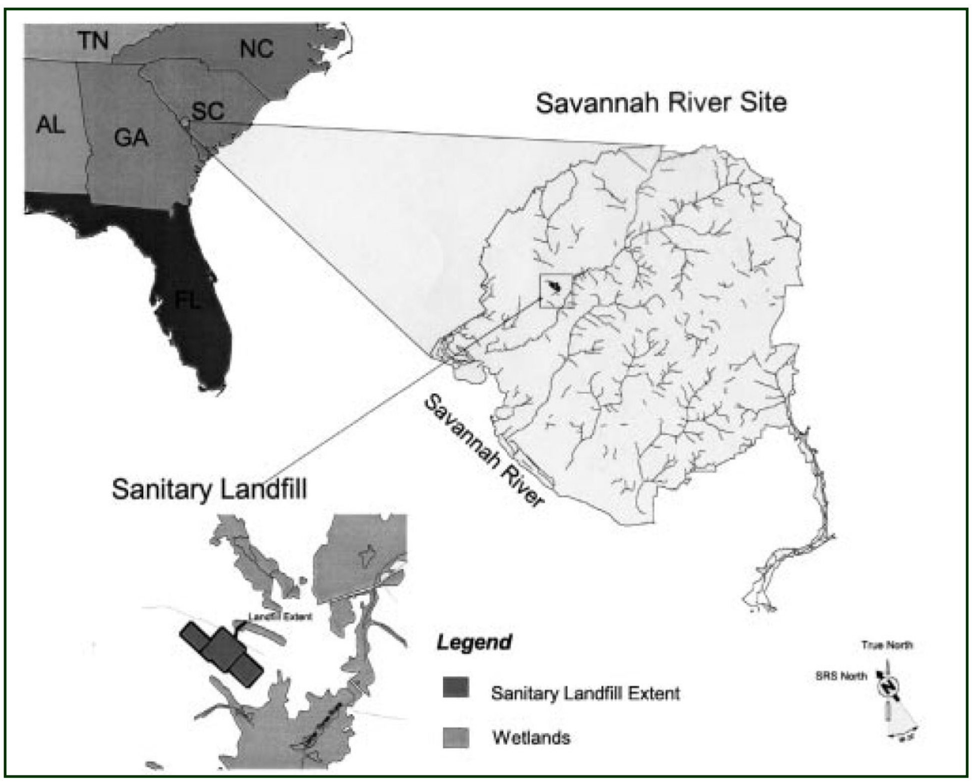
Cost and Performance Summary Report

Biosparging at the Savannah River Site Sanitary Landfill, Aiken, South Carolina

Summary Information [1, 2, 3, 5, 6]

The U.S. Department of Energy (DOE) Savannah River Site (SRS) is a 310 square-mile facility located near Aiken, South Carolina. Since 1950, the site has been used by DOE for the production of nuclear materials, with five production nuclear reactors having been built and operated at the site. From 1974 to 1994, a variety of wastes from SRS were disposed of in the unlined SRS Sanitary Landfill (SLF). These wastes included sanitary wastes such as office waste and cafeteria waste, wastewater treatment sludge, and solvent-contaminated wastes, including Resource Conservation and Recovery Act (RCRA)-listed solvents. The 70-acre SLF, shown in Figure 1, is located in the northwest quadrant of SRS. The landfill includes a main section (33 acres) and two expansion areas – a 22-acre southern expansion area and a 16-acre northern expansion area.

Figure 1. Location of the Sanitary Landfill at the Savannah River Site [1]



Groundwater monitoring of the SLF began in 1975, with the network expanded to 90 wells for RCRA compliance monitoring. In 1988, results of groundwater monitoring showed elevated levels of chlorinated solvents. The source of the contamination was tied to solvent-soaked rags and wipes disposed of in the landfill. While records were kept about the type of waste in the SLF, the exact location of the rags and wipes within the landfill were not known. The primary contaminants of concern included trichloroethene (TCE), cis-1,2-dichloroethene (DCE), and vinyl chloride.

The contamination at the SLF was addressed under RCRA. In 1996, the South Carolina Department of Health and Environmental Control (SCDHEC) approved a closure plan for the SLF, which included the installation of a low-permeability geosynthetic cap (engineered RCRA cap). The seven-layer cap included a geosynthetic reinforcement layer, a gas ventilation layer, a bentonite mat, a flexible membrane layer, and a geocomposite layer, with grass vegetation planted in the soil cover. The cap was designed to reduce infiltration and enhance reductive dechlorination of contaminants in the groundwater beneath the landfill. From 1996 to1997, the cap was installed over the main section and southern expansion area of the SLF, which were certified closed in October 1997. The cap reduced infiltration by more than 99 percent.

Since cap installation, anaerobic conditions (as evidenced by low-dissolved oxygen levels facilitating reductive dechlorination of TCE) have been observed at the site. Concentrations of TCE and cis-1,2-DCE have decreased; however, in June 1999, vinyl chloride concentrations were detected at levels of 480 µg/L.

In October 1999, biosparging was added to the SLF to volatilize TCE and vinyl chloride and to enhance the growth of naturally-occurring microbes to aerobically degrade TCE and vinyl chloride. Two horizontal biosparging wells were installed in the saturated zone south and southeast of the SLF to intercept contaminants in the groundwater. One well was used to stimulate the growth of methanotropic organisms to complete the mineralization of TCE accomplished by the injection methane, air, and nutrients. The second well was used to promote the aerobic degradation and volatilization of vinyl chloride by the injection of air and nutrients. In January of 2001, methane injection was terminated. According to DOE, TCE concentrations had decreased substantially and the benefits of additional injections were determined to be limited. Injection of air and nutrients in the two wells is continuing and the system will continue to operate until the cleanup goals are met. Groundwater monitoring will continue during the post-closure period.

Type of Action	RCRA Corrective Action

Timeline [1, 2, 5]

Date(s)	Activity
1996 – 1997	Engineered cap installed
October 1997	Main section and southern expansion certified closed
October 1999 to present	Biosparging conducted
January 2001	Methane injection stopped

Factors that Affected Cost or Performance of Treatment [3, 5]

The three significant hydrogeologic units at the SLF, from the surface, are (1) the unconfined Steed Pond Aquifer (SPA), (2) the Crouch Branch confining unit, and (3) the Crouch Branch Aquifer. Contamination occurs in the shallow portions of the SPA only.

The SPA is a water table/unconfined aquifer consisting of interbedded sands and clayey/silty sands. The SPA ranges in thickness from 180 ft in the northwest corner of the SLF to 120 ft in the southeast corner (including the vadose zone). The depth of the water table ranges from approximately 60 ft bgs in the northeast corner of the SLF to 30 ft bgs in the southeast corner. Shallow groundwater in the SPA flows to the southeast and is mostly horizontal, with a downward component in recharge areas and an upward component in discharge areas. Sources of groundwater for the SPA include precipitation and inflow from areas northwest of the SLF. The SPA is underlain by a competent confining unit.

The Upper Three Runs Creek is located approximately 3,500 ft southeast of the SLF, with a wetland area located between the SLF and the creek. The shallow groundwater in the SPA discharges to the wetland area. The seepline in located in the wetlands where groundwater seeps out variably and is dependent on precipitation rates and local topography. Due to this location, the seepline is affected by seasonal rainfall patterns and drought.

Listed below are the key matrix characteristics for this technology and the values measured for each during site characterization.

Matrix Characteristics [1, 5]

Parameter	Value
Clay content and/or particle size distribution	< 1% Gravel 75% Sand 12% Silt 12% Clay
Hydraulic conductivity	Range of 0.002 to 8.6 x 10^{-8} m/s (average of 1 x 10^{-5} m/s)
Presence of NAPLs	No
Depth to groundwater	30 ft bgs

Treatment Technology Description [1, 2, 3, 5]

The SLF biosparging system, which began operating in October of 1999, includes two horizontal wells (SLH-1 and SLH-2). The injection pad includes a compressor, a header for each well, NO_2 cylinder and triethyl phosphate drum, and methane vents that discharge directly into the air. Initially, one well was used to inject methane, air, and nutrients (nitrous oxide and triethyl phosphate) into the saturated zone to stimulate the growth of methanotropic (methane oxidizing) organisms to complete the mineralization of TCE. The second well was used to inject air and nutrients into the saturated zone to aerobically degrade and volatilize vinyl chloride.

The wells were installed using angle drilling to a depth of about 60 ft bgs (30 ft below the water table) and situated directly below the vertical center of the TCE plume. Figure 2 shows the well locations. SLH-1, located south of the SLF, has a horizontal well screen length of 800 ft. SLH-2, located to the southeast of the SLF, has a horizontal well screen length of 900 ft. The wells include a 6-inch diameter outer casing of carbon steel with holes (0.17% open area), and a four-inch inner casing of high-density polyethylene liner with varied slit spacing to distribute injectate (0.28% open area). The groundwater monitoring network at SLF includes 90 monitoring wells, as well a piezometers to monitor groundwater levels. Figure 3 shows the layout of the treatment zone relative to the vinyl chloride plume and the SLF.

In 1996, prior to full-scale operation, pilot-scale optimization testing was performed. The results showed that additional nutrients were needed in SLH-1, while air injection was adequate for bioremediation in SLH-2. When full-scale operations began in October of 1996, the system operated on a pulsed injection schedule. Methane was initially injected into the subsurface in one well. Air was then injected for 48 hours in both wells at 240 standard cubic feet per meter (scfm) in SLH-1 and 270 scfm in SLH-2 on a two-week cycle. After 24 hours of air injection, nutrients (nitrous oxide and triethyl phosphate) were injected for eight hours.

In January 2001, methane injection was stopped. According to DOE, TCE concentrations had decreased substantially and the results of numerical modeling predicted that further methane injection would not be beneficial. Presently, only air and nutrients (nitrous oxide and triethyl phosphate) are injected into both wells. The plan for the system is to cycle on and off as needed for the next 5 years and to continue monitoring.

Numerical modeling was performed for several purposes including: (1) to predict vinyl chloride concentrations in relation to potential points of exposure and the overall time required for system operation; (2) to simulate the effects of natural attenuation processes without biosparging; and (3) to predict whether vinyl chloride would exceed the Maximum Contaminant Level (MCL) at the seepline. MODFLOW was used to establish the groundwater flow field in and around the landfill; RT3D to simulate transport of TCE and vinyl chloride; and TRAMPP to simulate the bioactive zones above the biosparging wells. Specific results were not provided in the available references.

Figure 2. Horizontal Wells SLH-1 and SLH-2 [1]

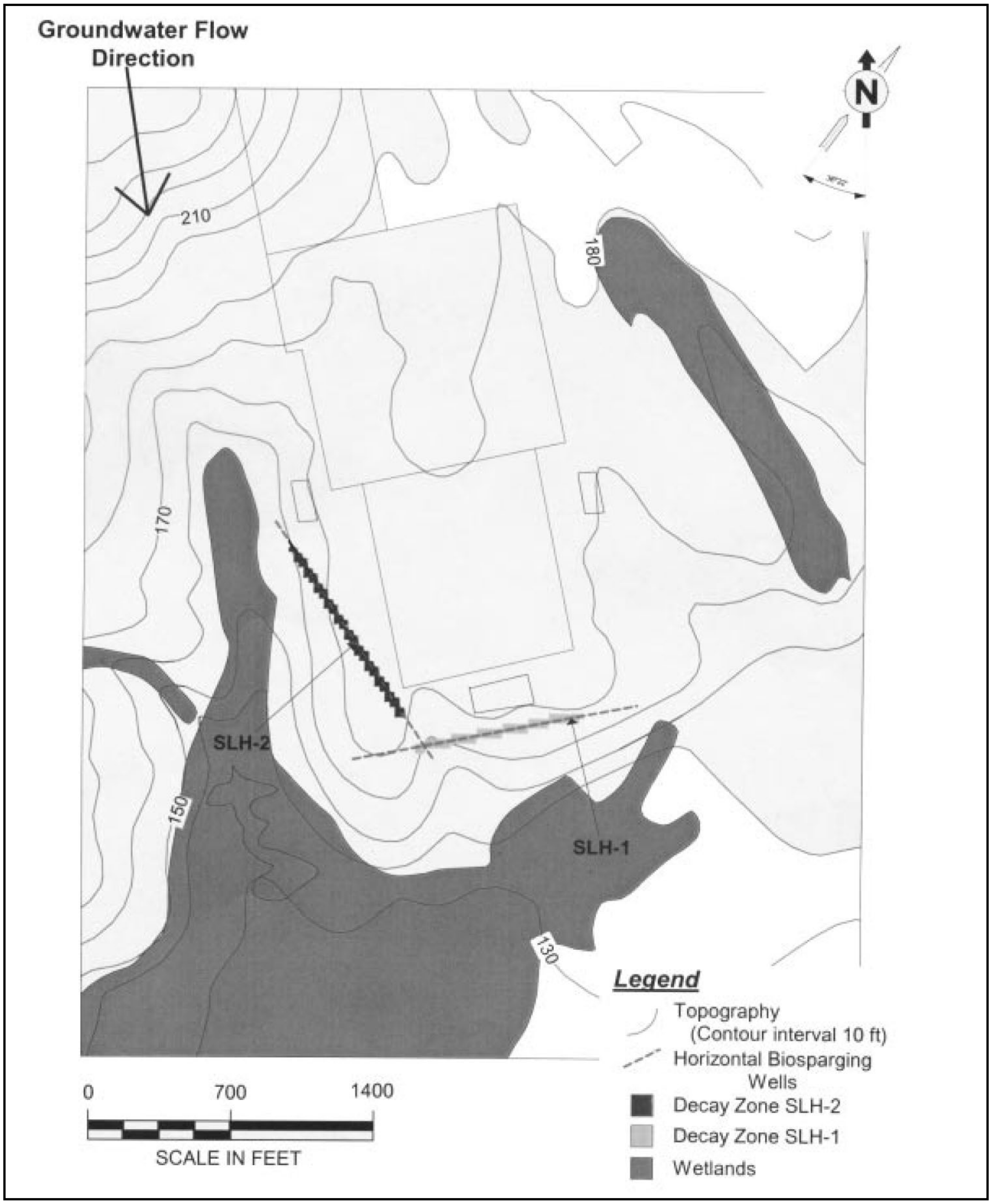
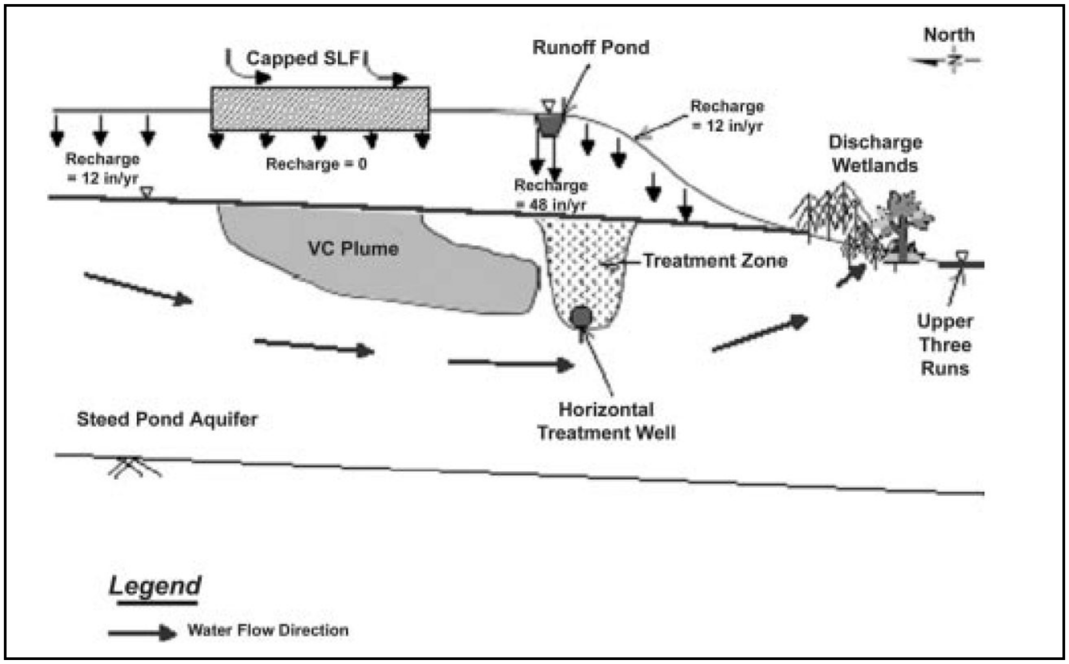


Figure 3. Layout of the Treatment Zone Relative to the Vinyl Chloride Plume and the SLF [1]



Operating Parameters [1,3,5]

Operating Parameter	Value
Air flow rate	SLH-1: 240 scfm; SLH-2: 220 - 250 scfm
Operating pressure/vacuum	SLH-2: 17 pounds per square inch (psig)
Nutrients and other amendments	Triethyl phosphate and nitrous oxide (0.005% and 0.048% of total air/month)
Microbial activity	From treatability testing, biostimulated microbes capable of reducing 100 mg/L of chlorinated ethenes in groundwater to non-detect levels
Oxygen uptake rate	Not available

Performance Information [1, 3, 4, 5,6]

The initial levels for groundwater monitoring at the point of compliance for the site were based on MCLs. For the SLF closure criteria, SRS negotiated with the state for Alternate Concentration Limit/Mixing Zone Concentration Limits (ACL/MZCLs). These levels, shown in Table 1. were the maximum concentrations allowed in groundwater at the point of compliance, and are the shutdown criteria for the biosparging system. The basis for the ACLs included human health and ecological risk assessments, as well as groundwater fate and transport modeling.

Table 1. Alternative Concentration Limits for Contaminants [4]

Contaminant	ACL/MZCL (µg/L)
Vinyl chloride	12
Tetrachloroethene	21
Trichloroethene	21
cis-1,2-Dichloroethene	287
Methylene chloride	21
Benzene	21

As of Fiscal Year (FY) 2003, the maximum TCE concentrations ranged from not detected at wells in the interior of the landfill to a maximum of 8 µg/L at point of compliance wells upgradient of the treatment system. In the monitoring wells downgradient from the horizontal treatment wells, TCE was not detected at a quantifiable concentration (< 2 µg/L). Vinyl chloride concentrations have continued to decrease over the past year, with maximum concentrations during FY 2003 reaching 80 µg/L in an interior landfill monitoring well, and 14 µg/L in a point of compliance well at the base of the landfill (upgradient from the treatment system). In wells downgradient from the treatment system, vinyl chloride has not been detected. Westinghouse Savannah River Company indicated that biosparging reduced concentrations in a well in the treatment zone by 99 percent for vinyl chloride and 75 percent for TCE.

The estimated volume of water that has moved through the treatment zone is 9.4 billion gallons. The estimate is based on 760,000 gallons/day[1] and an operating period of 4.5 years (1,643 days) which results in 1.2 billion cubic feet.

The system will continue to operate until the ACLs are met. According to Westinghouse Savannah River Company, when the ACLs are met, SRS plans to leave the biosparging system on stand-by. If additional groundwater contaminants are detected at the point of compliance wells then the system will be restarted as needed for a few years.

Cost Information [3, 5]

Westinghouse Savannah River Company provided information about the actual costs for the biosparging system at SLF. The cost for the injection of two horizontal injection wells (SLH-1 and SLH-2) totaled $1 million. Construction of the injection pad/well piping was reported to be $750,000 and the cost for operation of the biosparging system was $225,000 per year. In addition, the cost of groundwater monitoring was $215,000 per year.

Observations and Lessons Learned [5]

According to Westinghouse Savannah River Company, the use of biosparging at the SLF, in conjunction with a geosynthetic cap, reduced contaminant concentrations of TCE and vinyl

[1] Groundwater velocity of 100 ft/day x an average screen length of 850 ft x an average depth of treatment well below the water table of 30 ft x average porosity of 0.3

chloride in groundwater. The cap minimized infiltration and produced anaerobic conditions in the subsurface to facilitate reductive dechlorination of TCE. Biosparging was then added to volatilize TCE and vinyl chloride and enhance the growth of naturally occurring microbes to aerobically degrade these contaminants. In addition, Westinghouse Savannah River Company noted that the $10 million cost of the cap saved $6-7 million by using geosynthetics versus earthen materials.

According to the State, reducing conditions below the landfill helped degrade trichloroethene, but caused the vinyl chloride groundwater contaminant plume to increase. The current rate of growth of the vinyl chloride groundwater contaminant plume is insignificant. Future increases in the concentration of vinyl chloride in groundwater below the SLF are limited by the small mass of dissolved trichloroethene, its precursor, and by the presence of the landfill cap that prevents additional leaching of contamination from above.

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2. Biosparging Technology Successful at Removing Contaminants at SRS. Hazardous Waste/Superfund Week. Vol. 25 No. 25. June 23, 2003. Pages 241-242.
3. Email from David Noffsinger, Savannah River Co., to Sankalpa Nagaraja, Tetra Tech EMI. Subject: Response to Request for Information About the SLF Biosparging System for a US EPA Case Study. November 14, 2003.
4. WSRC. Sanitary Landfill In Situ Bioremediation Optimization Test, Final Report. WSRC-TR-96-0065, Rev. 1, April 1, 1996.

5. Comments received from David Noffsinger, Savannah River Co., on the Cost and Performance Summary Report on Biosparging at the Savannah River Site Sanitary Landfill, Aiken, SC, March 23, 2004.
6. Comments received from David Noffsinger, Savannah River Co., on Cost and Performance Summary Report. on Biosparging at the Savannah River Site Sanitary Landfill, Aiken, SC, May 13, 2004

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